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Invasive Vertebrate Species and the Challenges of Management

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ABSTRACT: Invasive vertebrates have had significant effects on native species, ecosystem processes, human health and economies around the world for more than 200 years. However, in the last 30 years, the breadth and impact of invasive species has accelerated with the growth and integration of high speed transportation networks. The effects of many non-native species are often difficult to predict prior to establishment. Current efforts to manage invasive species can be broken into the areas of prevention of introduction and detection of incipient populations, documentation of impacts, and development and implementation of management tools. We address various aspects of these areas under the broad headings of 1) invasiveness and pathways, and 2) impacts, managements, and challenges. One of the biggest challenges of invasive species management is the lack of interest and resources to manage species before they are established. Hence, few tools exist to manage populations once a population is established. As such, much of the focus of current research is dedicated to identifying the impact of species and the development of management tools. Further, these new tools must not only be effective but also adaptable to the ever changing dynamics of the economic, social, and ecological aspects of the locality invaded. The symposia at this conference on various invasive vertebrates highlight both successful and unsuccessful management efforts, investigations to determine the full impact of invasive species, and the development of novel control techniques.

KEY WORDS: eradication, management, invasive species, vertebrates, wildlife damage

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INTRODUCTION

Over 1,000 vertebrate species have been introduced into the United States. This includes 86 species of mammals, 127 species of birds, 126 species of reptiles, 53 species of amphibians, and over 673 species of fish (Witmer and Fuller 2011). Many of those species were native to some regions of the United States, but were moved to other regions. However, not all introduced species are invasive. An invasive species is simply a non-native species that may impact the economy, agriculture or human health and safety (NISC 2008). It is also important to remember that not all non-native species are invasive. Most food crops are non-native, and a species may have positive and negative effects. For example, feral pigs (*Sus scrofa*) may damage crops and harbor diseases, but they are also valued by others for hunting opportunities and as a source of "bush meat."

Some people have the idea that invasive species should no longer be singled out because they have been here so long. People have gotten used to seeing European starlings (*Sturnus vulgaris*), rats (*Rattus* spp.), pigeons (*Columba livia*), and pigs and believe that there isn't anything new coming. However, on many Pacific Islands, new species are still becoming established. For example, at least 6 frog species have become established on Pacific islands in the last 10 years, including brown tree frogs (*Polypedates megacephalus*), coqui frogs (*Eleutherodactylus coqui*), ornate frogs (*Microhyla pulchra*), greenhouse frogs (*Eleutherodactylus planirostris*), black spotted frogs (*Rana nigramaculata*), and the Malayan narrow mouthed toad (*Kaloula pulchra*). These species have come from as far away as the Caribbean and cause economic and ecological harm.

When we look at snakes pulled out of cargo or out of

airplanes, we find two cobra snakes (*Naja* spp.), water snakes (*Nerodia* spp.), garter snakes (*Thamnophis* spp.), beauty snakes (*Elaphe taeniura*), and kraits (*Bungarus* spp.). Several of these species have turned up multiple times in aircraft or cargo. Also, garter snakes frequently turn up in mainland plant shipments across the Pacific. Kraus (2009) and Lever (2003) reviewed the many reptile and amphibian introductions around the world.

INVASIVENESS AND PATHWAYS

So what makes a good invasive species or what causes one species to become widespread? In general, species that have high reproductive rates can quickly establish new populations. If a species has a wide variety of food preferences, it is able to take advantage of available resources in a new area. Species that are small or secretive do well because they can avoid interdiction efforts and go undetected while becoming established. Species that have a wide tolerance to climate have more opportunities to invade and are able to survive in transport. Because many transportation opportunities are in population centers, species that live in close proximity to people are more frequently transported. Some places are also more vulnerable to invasive species. Transportation hubs allow for greater opportunities for invasion and obviously, more species can adapt to less extreme climates. Areas that are geographically isolated tend to have fewer native species that may compete or prey on a recently introduced species. Additionally, habitats that have been altered by people or other invasive species provide opportunities for species to come in.

There are many reasons that we find more invasive species showing up around the Pacific and around the world. The entire Pacific basin is changing with popula-

tion growth and development on many islands, which leads to more construction and the need for more materials to be moved in. Agriculture is shifting away from traditional monoculture crops, such as sugarcane and pineapples. This is being replaced by smaller diversified crops which are in demand worldwide, including tropical fruits, flowers, and tropical plants. Now you can walk into almost any home improvement center and pick up tropical plants or go into a grocery store and buy tropical fruits year round. The other driver is the increase in global connections by aircraft. Long, slow boat trips are being replaced by overnight flights, so more animals in shipments are now able to survive the journey. Tourism is also increasing as people look for more remote areas to vacation.

Animals are introduced into new areas intentionally or accidentally. Many other animals are accidentally introduced as stowaways in cargo, ships, and airplanes, but they can also be the result of pet escapes. Governments or people introduce animals intentionally because they want new food resources, they need farm animals, they want new animals to hunt, they just like the species or want to keep it as a pet, or they think it could be used to control another animal. Many of the animals historically introduced fall into these categories. Accidental introductions in the Pacific include frogs brought in on plant shipments, or snakes and geckos moved in cargo. Historically, rats and cats (*Felis sylvestris*) have been moved around the globe accidentally aboard ships. Kraus (2003) reviewed some of the pathways of vertebrate introductions.

Many people across the world desire pets, and increasingly rare or exotic pets are brought in (Jenkins 2007). Often these pets escape and become feral. Feral dogs (*Canis familiaris*) and cats fall into this category, but more recent examples include parrots, chameleons, and snakes. There are numerous examples of purposeful introductions starting with horses (*Equus caballus*), goats (*Capra hircus*), sheep (*Ovis aries*), and game birds introduced hundreds of years ago. In response to other invaders, mongoose (*Herpestes auropunctatus*) were moved around the world to combat rats, cane toads (*Bufo marinus*) to control insect pests, and poison dart frogs (*Dendrobates* spp.) and other frogs to combat mosquitos. Other intentional introductions include species that were brought and released because people enjoyed them. Some recent examples of releases are more insidious and involve smuggling.

Many of us have seen news reports of people caught smuggling exotic animals into countries around the world. Often this is done for economic reasons, and the risk of getting caught is worth the price people are willing to pay for the animals. Live animals are difficult to detect by most security measures, and the primary equipment like metal detectors and x-rays do not pick up many animals. More recent security measures like body scans are more effective at detecting animals.

IMPACTS, MANAGEMENT, AND CHALLENGES

So what is the impact of the introduction of numerous invasive animals? Invasive species may impact ecosystems, economics, and human health and safety.

Invasive species prey on native species, compete with native species for food, and destroy native habitats. Invasive species have been implicated in the demise of more than half of the species listed as endangered. The cost of damage and to manage invasive species has been estimated at more than \$130 billion annually (Pimentel 2011). Animals damage crops, homes, and may impact trade between countries. Additionally, invasive species may transmit disease and have other impacts to human health and safety. Numerous examples of invasive vertebrate impacts have been presented in the papers of various conference proceedings (e.g., Veitch and Clout 2002, Veitch et al. 2011, Witmer et al. 2007).

Managing invasive species is a challenge because often they are difficult to detect and damage may go unnoticed for a period of time. Another challenge is the need to develop new methods to manage or detect species. Frequently we turn to traditional tools to manage new species, but our ability to control a new invasive species often requires the development of novel tools. This was certainly the case with the brown tree snakes (*Boiga irregularis*) in Guam. There may be resistance to control efforts before effects are widespread, because most people do not see the need. Further, some people do not like management of animals (e.g., feral cats) that are commonly kept as pets. The final challenge is funding for invasive species management, where there is less support for interdiction efforts and the costs to mount large-scale efforts against well-established species are extremely high.

Most of the management and research for invasive species can be put into two categories. Prior to a species being well established, efforts are focused on prevention and early detection, and awareness of potential impacts. During this time, it is critical that there is good communication among groups so there is no duplication of effort and there is a clear channel to report new introductions or incipient populations. After a species is well established, efforts move toward documenting the effects of invasive species and the development of control strategies. Public education is critical throughout both stages. However, the same line used to demarcate the establishment of a species could also be called the money line. Before a species is well established, there is limited funding to do research and management. The primary reason for this lack of funding is the lack of public interest and knowledge of potential consequences. Why spend money now if we don't have to? However, prior to a species becoming widespread, the cost to mount control efforts is lower and the probability of success is higher. Once a species is well established and is having ecosystem, economic, and/or human health effects, public interest increases and funding becomes available. It is suddenly realized that we need to do something about this growing problem. However, at this point the cost to manage a species is higher and the probability of successfully eradicating a species is lower. If we can shift our efforts and resources to developing tools for interdiction and preventing new species from becoming established, we can manage invasive species much more effectively. Numerous examples of invasive vertebrate control and eradication strategies and tools have been

presented in the papers of various conference proceedings (e.g., Veitch and Clout 2002, Veitch et al. 2011, Witmer et al. 2007). There are published reviews on the many methods and successes of eradicating rats (Howald et al. 2007), feral cats (Nogales et al. 2003), and feral goats (Campbell and Donlan 2005).

This volume contains the papers from a full-day symposium on invasive species. It also contains papers from special symposia on invasive pigs, cats, and rodents. Here we provide examples of the issues that are covered in some of those papers. Snakes are difficult to detect in the wild and difficult to control. Brown tree snakes arrived on Guam shortly after World War II, but they remained largely undetected as a threat for more than 30 years. Prior to the management of brown tree snakes, few techniques existed for the management of snake populations. Burmese pythons (*Python molurus*) have more recently become widespread in Florida. Both species have caused widespread ecological effects and have decimated native wildlife as they spread. They also affect tourism and present human health and safety issues.

Although many invasive birds have been around for a long time, new species are becoming established. More than 36 species of non-native parrots have been recorded in Hawaii alone. Warmer mainland areas in Florida, Texas and California also have sizeable parrot populations. Most of these species were introduced via the pet trade. Wild parrot populations may damage agricultural crops, cause property damage, be a reservoir of disease, and spread invasive plants. Mynah birds (*Acridotheres tristis*) compete with native species for resources and cause property damage. Agencies are renewing efforts to manage this species in American Samoa. Lever (2005) and Long (1981) reviewed the many bird introductions around the world.

Many species of mammals have invaded most parts of the world. Some are recent invaders and some have been around for a long time. One common theme around the management of invasive mammals has been the interest of public groups having very diverse opinions on management. Invasive sheep in Hawaii impact plants which in turn impacts native birds. Sheep were originally brought in for food, and their management has been difficult over large areas. Management of feral horses is challenging in the United States and Australia where there is public opposition to horse management. However, novel approaches to these challenges have brought about better management. Brush-tail possums (*Trichosurus vulpecula*) have been difficult to control in New Zealand. They harbor disease that threatens agriculture and they also compete with some native animals and prey on others. Long (2003) reviewed the many mammal introductions around the world.

CONCLUSIONS

Over 1,000 species of introduced vertebrates occur in the United States and its territories, and there will probably be many more introductions whether accidental or intentional. Hence, one can surmise that introduced vertebrate species will continue to challenge land and resource managers, ecologists, and biologists for a long time to come. Hopefully, some invasive vertebrate

species will be eradicated or die out on their own over time. In the United States, there have been some good successes with invasive species management and eradications, especially on islands, but also on some areas of the mainland. As a result of this, along with our collaborations with international colleagues and a growing interest and involvement by the public and agencies, we are becoming more knowledgeable and proactive in responding to invasive vertebrate species. Areas for progress include national organization and cooperation on these issues, resolving various logistical and financial issues, and improving methods and strategies for many more species.

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